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LANDSAT DATA CONTINUITY MISSION

SPECIAL CALIBRATION TEST REQUIREMENTS

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1. Introduction

The LDCM program elements are dependent on the pre-flight and on-orbit commissioning phase characterization and calibration of the imaging sensor and related subsystems, and, in particular, on the data sets and written reports from those tests. It is through the preflight test reports that the required elements of the Image Assessment System will be identified. In addition, the algorithms and input parameters to process the image data will be developed using these preflight data sets.

The purposes of the pre-flight and commissioning phase test requirements are to:

- verify that the instrument's operation conforms to specifications;
- establish the instrument's as-built performance;
- test for abnormalities in the sensor's response;
- provide an at-launch estimate of the sensor's radiometric calibration;
- provide characterization data sets that are otherwise unobtainable in flight or on the ground (such as spectral band characteristics, PSF parameters, and solar diffuser reflectance); and
- determine the instrument's radiometric stability.

The LDCM contractor has the responsibility for providing an observatory capable of providing well calibrated, well characterized and specification compliant data, to ensure Landsat data continuity. The Government has the responsibility for independently assuring that the delivered system will be specification compliant and sufficiently well calibrated and characterized to fulfill the Mission objectives. The following Special Calibration Test Requirements (SCTR's) are an essential component of that independent assurance program.

The following test requirements do not constitute a complete set of tests. The Contractor is responsible for verification and validation of <u>all</u> LDCM requirements. The tests described herein shall be included as part of the Contractor's overall validation program as required in the Calibration/Validation Plan CDRL (CV-1). The contractor shall report the results of these tests in accordance with the Calibration/Validation Test Report CDRL (CV-3).

2. General Test Requirements

2.1) Sampling methods and their statistical validity shall be described in the calibration/validation plan CDRL CV-1.

2.2) Tests specified to be performed over the range of instrument operating conditions shall sample the range of conditions expected during on-orbit operations.

2.3) All radiance calibration sources and transfer radiometers used by the contractor prior to launch shall be calibrated to National Institute of Standards and Technology (NIST) standards for radiometric calibrations.

3. Pre-flight Test Requirements

3.1) Spectral test requirements

Prior to launch, the contractor shall:

3.1.1) Characterize the relative spectral radiance response for each band of the instrument and the variation of this response within the band.

i. The relative spectral radiance response of a representative sample of detectors, the spectral transmission or reflectance of a representative sample of the optical elements and the spectral transmission of the spectral bandpass filters shall be measured at the component level.

ii. The in-band (between 1% response points) relative spectral radiance response shall be measured at the integrated instrument level under simulated on-orbit operating conditions (vacuum and focal plane temperatures). If only a representative sample of detectors are tested, then this sample shall include at least 10% of the detectors in each band uniformly distributed across the focal plane, i.e., samples from center and edges of each sensor chip assembly.

iii. The out-of-band relative spectral radiance response of the instrument shall be determined down to a sensitivity of 5 orders of magnitude (below the peak in-band value) across the wavelength range of the sensitivity of the detectors used in the particular band. This determination shall be based on measurements of the mirrors as well as measurements made after detectors are mated to filters or at higher levels of assembly. The detector/filter measurements shall be made under operational temperature and angular conditions with adjacent bands illuminated. The integrated out of band response shall be determined using the solar Top of Atmosphere (TOA) curve in section 6.2.3 of the instrument specification as a weighting function.

3.1.2) Characterize the stability of the spectral transmission of the spectral band bandpass filters between ambient pressure and vacuum conditions at their expected operating temperature and angular conditions. Witness filters shall be measured in ambient and daily over 7 days of continuous vacuum exposure.

3.2) Spatial test requirements

Prior to launch, the contractor shall:

3.2.1) Characterize the spatial edge response based on measurements at the integrated instrument level under simulated on-orbit operating conditions (vacuum and temperatures) for a representative sample, i.e., 11 field angles (Scale Factors of Field of View (FOV): -1, -.89, -.77, -.63, -.44, 0, .44, .63, .77, .89, 1.0) across the entire FOV in all bands. Examine edge spread response data for possible crosstalk between spectral bands on the same focal plane.

3.2.2) Demonstrate the edge slope response of the instrument VNIR bands remains within specification following observatory-level vibration testing.

3.2.3) Characterize the stray light rejection and internal light scattering of the instrument based on measurements at the component level or above and analysis. The stray light model shall be developed using a Government-approved non-sequential ray trace method, e.g. ASAP, APART, GUERAP, Trace Pro. The stray light model shall encompass the spacecraft and other spacecraft instruments and the entire optical system, including baffles and the focal plane, detectors and mounting devices. Include a stray light analysis of the solar diffuser panel(s) in the deployed position. This analysis shall include glints and shadowing on the diffuser by other observatory structures as well as the instrument itself. As part of this analysis, demonstrate that diffuser measurements on orbit are not contaminated by reflected light from the earth and the atmosphere. Collect data at the integrated instrument level sufficient to look for instrument stray light effects not predicted by the stray light model. Characterize all applicable spectral bands to allow for possible improvements to the instrument stray light model. Included within this general stray light characterization and analysis special test requirement are measurements and analysis to confirm a more specific type of stray light, which is addressed in the ghosting system specification requirements. In tests at the integrated instrument level associated with this requirement verification, the minimum size object diameter for testing will be equivalent to the larger of an enclosing diameter of 1/10 of the FPA across-track FOV or twice the SCA extent.

3.3) Radiometric test requirements

Prior to launch, the contractor shall:

3.3.1) Radiometrically calibrate all detectors at the integrated instrument level in absolute units under simulated on-orbit operating conditions (vacuum and focal plane temperature). Characterize the calibration across the expected instrument operating temperature range. Collect sufficient calibration data sets and characterization data to demonstrate that the calibrated data will meet the absolute radiometric accuracy, radiometric signal to noise, and radiometric stability requirements on orbit.

3.3.2) Determine the mathematical equation(s) to convert the instrument output in DN to input radiance in W/m^2-sr-μm. Demonstrate the validity of the equation(s) with integrated instrument level measurements for a sampling of detectors.

3.3.3) Characterize the on-board solar calibrator for on-orbit use. This shall include characterization of the spectral bidirectional reflectance of the solar diffuser panel across the range of solar incidence angles and focal plane view angles to be used on orbit.

3.3.4) Characterize additional on-board calibration devices for on-orbit use. This shall include characterization of the stability of the internal calibration lamp system. Provide an integrated instrument level observation of at least one device that is expected to be radiometrically stable through launch. This observation shall be repeatable on orbit to assess the transfer of the pre-launch radiometric calibration to on-orbit calibration (i.e., Transfer to Orbit Measurement).

3.3.5) Characterize the Signal to Noise Ratio (SNR) of all detectors with integrated instrument level measurements under simulated on-orbit operating conditions (across the on-orbit sensor temperature range and in vacuum) and across the dynamic range of the instrument.

3.3.6) Characterize the relationship between the biases of all imaging and dark reference detectors for each SCA with integrated instrument level measurements under simulated on-orbit operating conditions (across the on-orbit sensor temperature range and in vacuum).

3.3.7) Characterize the bias stability and noise levels of all imaging and dark reference detectors with integrated instrument level measurements under simulated on-orbit operating conditions (across the on-orbit sensor temperature range and in vacuum).

3.3.8) Characterize the detector bias and gain stability across on-off cycling of the instrument.

3.3.9) Characterize 1/f noise parameters baseline by measuring long dark collects and dark pixel collects under simulated on-orbit operating conditions (across the on-orbit sensor temperature range and in vacuum). Test includes, at a minimum, one 30-minute continuous data collect.

3.3.10) Characterize the coherent noise of the instrument with spacecraft level measurements under simulated on-orbit operating conditions including contributions from the spacecraft (across temperature range and in vacuum).

3.3.11) Characterize the linear polarization sensitivity of the instrument by component level measurements and analysis. Measure the linear polarization sensitivity of a sampling of detectors (center and edges of field of view) at the integrated instrument level.

3.3.12) Characterize the bright target recovery and pixel-to-pixel electrical crosstalk of the instrument by focal plane level or above level measurements.

3.3.13) Provide and maintain a detector operability status list which include dead, inoperable, and out-of-spec detectors for each band.

3.4) Geometric test requirements

Prior to launch, the contractor shall:

3.4.1) Characterize the instrument's lines-of-sight (LOS) via measurements of all detectors LOS relative to the instrument coordinate system.

3.4.2) Demonstrate the relative stability of the detector lines of sight by measuring the relative locations of a selected set of detectors from each band and each SCA over the expected range of operating temperatures, to an accuracy ≤ 1 μrad (1-sigma), at integrated instrument or observatory level, post-vibration. The selected set of detectors shall include, at a minimum, the first, middle, and last even detector, and the first, middle, and last odd detector from each band on each SCA.

3.4.3) Measure the alignment of the instrument optical axes relative to the observatory Attitude Determination System reference.

3.4.4) Demonstrate the instrument's band-to-band internal geometry stability over the expected range of operating temperatures.

3.4.5) Characterize the alignment of the attitude sensing devices provided with the observatory relative to the spacecraft Attitude Determination System reference.

3.4.6) Demonstrate the ability to accurately reconstruct and register images in the VNIR bands from data collected under conditions that simulate the on-orbit target motion. This demonstration may be performed in segments over the full FOV of the instrument. This demonstration shall also include, but not be limited to, post-environmental spacecraft-level ambient testing, using an external target.

3.4.7) Characterize the detector-sampling timing pattern via measurement of any detector-specific electronic delays, sample phasing (e.g., even/odd detector timing offsets), and frame rate (i.e., time between samples) for each detector.

4. On-Orbit Commissioning Phase Test requirements

4.1) Spatial tests requirements

During the Commissioning phase, i.e., prior to Initial Operational Capability, the contractor shall:

4.1.1) Characterize the stray light and ghosting of the instrument at least twice.

4.2) Radiometric test requirements

During the Commissioning phase, i.e., prior to Initial Operational Capability, the contractor shall:

4.2.1) Characterize on-board calibrator initial on-orbit performance and stability. Characterize the variation in the BRF of the solar diffuser across the range of azimuth and zenith angles to be used for on-orbit calibration. The Transfer to Orbit Measurement shall be completed (See SCTR 3.3.4).

4.2.2) Characterize the stability, absolute radiance calibration and absolute reflectance calibration of the spectral bands. Update the absolute calibration coefficients and uncertainties as required to meet performance specifications.

4.2.3) Characterize any variations in detector responsivity over a minimum of 2 instrument out gassing cycles, if required.

4.2.4) Characterize the relative detector response for detectors within a band and update the calibration parameters to correct pixel-to-pixel non-uniformity as necessary.

4.2.5) Characterize both the coherent and total noise of the instrument at dark and at multiple illuminated levels between dark and L_{high} at least twice.

4.2.6) Characterize: 1) the bias stability for all detectors, 2) the 1/f noise parameters for all detectors, and 3) the relationships between the biases of the dark reference detectors and the imaging detectors for each SCA over 30 minutes at least twice.

4.2.7) Characterize the performance of the bias determination algorithm using on-orbit data.

4.2.8) Image the full lunar disk at a phase angle of 5° to 9° or -9° to -5°. At least 2 SCA's shall image the moon at least twice during commissioning at the same phase angle, one lunar cycle apart. All SCA's shall image the moon at least once within the same 4° increment of phase angles.

4.2.9) If Landsat-7 is still operational, collect data of common ground targets within 20 minutes of the Landsat-7 ETM+ acquisitions.

4.2.10) Characterize the bright target recovery and crosstalk of the instrument.

4.2.11) Update the detector operability status list with newly identified dead, inoperable, and out-of-spec detectors for each band at least twice.

4.3) Geometric test requirements

During the Commissioning phase, i.e., prior to Initial Operational Capability, the contractor shall:

4.3.1) Characterize the instrument to Attitude Determination System Reference alignment.

4.3.2) Characterize the detector arrays lines of sight for each band on the focal plane(s) relative to the pan band at least twice.

4.3.3) Characterize the relative locations of the individual SCAs on the focal plane at least twice.